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R&D expenditures in liberalized electricity markets: The case of Turkey

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ABSTRACT

Current problems in the electricity sector require deployment of new technologies which are the outcome of research and development (R&D) mostly. On the other hand, figures show that government energy R&D expenditures have declined in many developed countries which mostly resulted from liberalization and restructuring. Moreover, studies indicate that private energy R&D expenditures have also been affected by the reform process. As a result, there are concerns about the declines in government and private energy R&D expenditures which may hamper the deployment of sustainable energy technologies. Similar to other countries, Turkey has initiated electricity market reforms, and it has been trying to establish a competitive electricity market since 2001. Moreover, it has increased its efforts to develop domestic low-carbon energy technologies. An assessment of the relation between R&D expenditures and liberalization in the Turkish power market shows that market reforms have created new demand and opportunities for equipment manufacturers, and there have been an increase in R&D expenditures performed by these companies. On the other hand, power companies have mostly refrained from performing R&D expenditures due to their perception of R&D expenditures as unnecessary as well as insufficient incentives, lack of funds and uncertainties stemming from liberalized market framework.

Contents

1. Introduction

The problems that electricity sector encounters such as security of energy supply, environmental degradation and sustainable development concerns necessitate deployment of more efficient, less polluting and cheaper power sources and technologies. One, perhaps the only method to overcome these challenges is the development of new technologies in order to transform electricity sector into a more efficient and sustainable pattern. In this respect, technological innovations and R&D expenditures play an essential role in the creation of new technologies. On the other hand, studies show that government energy R&D expenditures have decreased significantly in almost all OECD countries since the beginning of 1990s, dates corresponding to introduction of liberalization in power industry. Moreover, private sector energy R&D expenditures have also declined due to the fact that enterprises have focused on low-risk, low-cost and customer-oriented short-term R&D expenditures with the liberalization of electricity sector in many countries. However, transforming electricity sector into a more sustainable pattern requires long-term R&D expenditures from which enterprises are currently refraining in liberalized electricity markets.

Similar to other OECD countries, Turkey has opted for electricity market liberalization, and it has been trying to establish a

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competitive and liberalized electricity market since 2001. Meanwhile, Turkey is struggling to develop domestic energy technologies, where power industry accounts greater importance as official policy documents indicate. However, these documents do not include adequate information about how R&D will play a role. Someone may argue that innovation and R&D are even neglected in energy policy discussions. Therefore, this article aims to assess the impact of electricity market liberalization on electricity R&D expenditures in order to enhance the scope of policy discussions. Section 2 summarizes an overview of literature regarding the relation between energy R&D expenditures and electricity market liberalization. Section 3 presents Turkey's general technology profile and the problems regarding innovative activities in Turkey. Then, Section 4 discusses R&D expenditures in Turkish electricity sector by examining government energy R&D expenditures and the results of survey conducted among electricity power companies and equipment manufacturers. Finally, Section 5 concludes the article.

2. Electricity market reforms and R&D expenditures

Technological innovation[3] or shortly innovation is the key for economic growth and wealth creation in modern economies [2]. Moreover, current problems of energy sector such as environmental degradation, energy security concerns, increasing costs of fossil fuels require significant efforts to develop cleaner and cheaper energy technologies [3]. However, technological innovation has some major differences from other investments that create positive externalities and uncertainties, and enterprises generally refrain from investing in innovative activities [4,5]. As a result, even if it is claimed that establishment of fully competitive markets will provide incentives and resources for innovation, government intervention is required to allocate enough resources for innovation in competitive markets [4,6–8].

Innovation in electricity sector has also some differences from that of other sectors. Electricity supply systems include both competitive and natural monopolistic activities [6], and these have strong interdependences among components and they function under strict standards for safety and reliability [9]. Therefore, innovations in this sector have to be compatible with the infrastructure and must not jeopardize the functioning of the system [9].

Electricity sector has experienced major changes in many countries during last two decades, namely electricity market restructuring, liberalization and deregulation which all aim to increase labor productivity and plants' performance, to promote innovative activities, and to increase service quality [10]. As firms have to offer competitive prices and high quality services to consumers in competitive markets, they are expected to use cost-efficient technologies which become profitable in short-term. Moreover, customer choices have begun to affect firms' investment decisions, and firms may perceive innovation as not only a mean to develop new technologies but also to improve firms' image in the eyes of customers [9]. As a result, it is expected that firms will focus more on innovation in order to gain competitive advantages in a liberalized market. On the other hand, risks and uncertainties associated with market liberalization are also claimed to hinder innovative activities in liberalized electricity markets [9,10].

The challenges of electricity market restructuring also affect R&D expenditures which are essential for technological innovation [7,11]. Market reforms have created both opportunities and risks for power companies, thereby affecting the quantity and the course of R&D expenditures. Increasing competition in liberalized electricity markets has forced power companies to use cheap, reliable and flexible power technologies, and the need for such technologies have created conducive environment for technological innovations. On the other hand, energy R&D expenditures are no longer oriented by government decisions only, and R&D budgets are determined by profit concerns of companies and shareholders [12,13]. Furthermore, rising risks and uncertainties in new markets may depress long-term R&D expenditures, and firms may engage in less-risky and less-costly R&D activities which will result in a product or a service in short term [7,11,14]. In addition, utilities could not pass their R&D costs to customers in deregulated markets contrary to regulatory markets which provided a safe environment for investments and guaranteed returns for investors. Besides, public utilities may also cut their R&D expenditures or may shift their R&D expenditures from long-term to short-term projects or customer-oriented projects in deregulated markets [15,16].

In addition to the effects on utilities and power companies R&D expenditures, liberalization also affects R&D expenditures of equipment manufacturers. As new consumers (such as eligible consumers) or new producers (such as Independent Power Producers) are permitted to enter the market, equipment manufacturers face new demand for their equipments, and this will have a positive effect on technological innovations and R&D expenditures made by these companies. On the other hand, as public utilities' R&D spending and funding decreases, manufacturers may not participate in risky projects alone, and they may also curtail their R&D expenditures [12]. Moreover, liberalization may also force cheaper equipment acquisition from foreign manufacturers instead of domestic ones which also affect domestic R&D expenditures adversely.

Overall, electricity market restructuring has alleged to have both positive and adverse impacts on electricity R&D expenditures. Nonetheless, the drivers of R&D expenditures are not only affected by market reforms, and many factors such as industrial capacity, trade openness, innovation system etc. affect innovation and R&D expenditures. Therefore, the impact of liberalization on R&D expenditures in power sector may differ from country to country.

3. An overview of Turkey's innovation profile

Turkey is the 17th biggest economy in the world[4], and it spent 9268 million TL (5.4 billion) USD for R&D in 2010 which equals to 0.84% of Turkey's GDP [18]. Although Turkey's science and technology policy making efforts dated back to 1960s, science and innovation profile of Turkey is still not ranked well. Until the end of 1990s, macroeconomic problems (such as high share of informal economy, high inflation, high interest rates and risk premiums) and inconsistent policies deteoriated the climate for innovation, and business sector refrained from R&D expenditures [19]. In 2001, after the worst economic crisis Turkey has ever encountered, new economic and structural reforms have been initiated. Since then, improving macroeconomic conditions, political stability and government's strong support for innovation created a favorable environment for new investments; nevertheless, Turkey still has a poor innovation performance and it is below the average, in many aspects, among OECD countries.

[3] Technological innovation activities are all of the scientific, technological, organizational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes [1].

[4] According to International Monetary Fund's World Economic Outlook data [17].

Turkey has one of the lowest Gross Domestic Expenditure on R&D (GERD) as a share of GDP among OECD countries, and its GERD as a share of GDP is only one-third of EU-15 average [20]. In 2010, R&D expenditures are mostly performed by universities (46%) whereas private sector performed 42.5% of total R&D expenditures, and public sector performed 11.4% in 2010 [18]. Similar to R&D expenditures, most enterprises in Turkey refrain from innovative activities, and only one-third of total firms engage in technological innovations in general, and industry sector has the highest share of firms engaging in innovative activities with 36% in 2010 [21]. During 2002–2008, the share of firms which engage in technological innovations has been around 35% in general. Nonetheless, the share of firms which engage in technological innovations in electricity, gas and water supply industry declined from 27.5% to 17.8% [22].

Turkey uses a variety of incentives to foster innovative activities and to increase R&D expenditures. Two essential laws, Law no.4691—*Law on Technology Development Zones* and Law no.5746 —*R&D Law* establish the main incentives for R&D expenditures. In addition, other laws and decrees provide incentives (tax exemptions or social security payments), financial support and state aids for enterprises those perform R&D activities. The main supporter of innovative activities and R&D expenditures is the Scientific and Technology Research Council of Turkey (TUBITAK). Besides TUBITAK, Ministry of Industry and Trade, Ministry of Education and Ministry of Finance are the main agencies in implementing R&D support programs. Turkey has also a number of state-owned research centers and institutes those perform R&D activities and collaborate with enterprises.

Turkey has been spending efforts to increase innovative activities and domestic R&D expenditures to protect its competitiveness and to overcome economic problems (high unemployment, low labor productivity etc.) it faces. However, there are some major problems that adversely affect innovation and R&D expenditures [23]. The first group of problems is related with the costs, financial issues and marketing problems. Due to low domestic savings, less developed capital markets and high risk perceptions, enterprises cannot provide sufficient funds from domestic or international capital markets for innovation. In addition, financial regulations limit access to venture capital, which is essential for new companies those have difficulties in raising funds from financial markets [24]. Furthermore, high initial costs hinder innovative activities, and enterprises have difficulties in getting early-stage funding to cover these costs.

The second group of problems is related with knowledge creation and collaboration among stakeholders. Lack of trained and skilled personnel creates problems in universities and enterprises. The number of researchers in Turkey has doubled during 2000–07; however, the number of researchers per 1000 employment is still one-third of EU average [20]. Besides, enterprises encounter problems in vocational training due to high training costs, and regulations deter personnel mobility between universities and enterprises [24]. Low collaboration among stakeholders is another crucial impediment to innovative activities, and the linkages among universities, government agencies and enterprises are weak which prevents commercialization of the knowledge created [19].

The third group of problems is related with institutional and legislative framework. Despite the fact that Turkey has mostly aligned its laws and regulations in line of *acquis communautaire*, there are problems in the implementation and enforcement of regulations those protect property rights and loyalties, and these problems create obstacles for innovative activities [19]. Moreover, rigidities in taxation and labor regulations induce informal economy and promote low-skilled jobs which prevent technological updating and innovative activities in enterprises [23,24].

In order to eliminate these problems, Turkish government initiated "Vision 2023 Project" in 2001. This project aims to create an "affluent society" which is competent in science and technology [23,25]. In line with "Vision 2023 Project", "Science and Technology Policy Implementation Plan" was adopted in 2005, and "International Science, Technology and Innovation Strategy" and "National Innovation Strategy" were adopted in 2007. Furthermore, "National Science Technology and Innovation Strategy 2011–2016" was adopted in 2010. These strategies aim to increase innovative activities and commercialization of knowledge, to strengthen collaboration among universities, enterprises and public agencies, to improve infrastructure and enhance legal framework, to increase demand for innovation and to increase the number of researchers and skilled personnel [23,25]. The strong commitment of government resulted in the enhancement of Turkey's innovation profile recently; however, the above mentioned problems continue to exist and a comprehensive science and technology policy with long-term perspective must be implemented to overcome these problems.

4. Liberalization of Turkish electricity sector and its impact on R&D expenditures

4.1. Electricity market liberalization in Turkey

Turkey has one of the highest electricity demand growth rate among OECD countries and its demand has increased 7.5% annually during 1984–2010. In 2010, a total of 211,207 GWh electricity was produced from coal (26.1%), hydro (24.5%), gas (46.5%), and other sources (2.9%) [26]. Due to low domestic oil and natural gas reserves, Turkey had to import more than two-third of its primary energy demand, and more than 90% of its natural gas and oil consumption. As a result of high import dependency, energy supply security has been a priority issue in Turkey's energy policies, and recent policies aim diversification of imports, utilization of domestic coal and renewable energy resources, and increasing energy efficiency to secure energy supply and decrease import dependency on fossil fuels.

Turkey has been trying to restructure its electricity sector since the beginning of 1980s, and it is amongst the first countries who introduced Built–Operate–Transfer (BOT) or Built–Operate–Own (BO) schemes in electricity sector, which were followed by several attempts aiming to increase private participation in electricity generation. Nonetheless, the desired level of private participation to power market could not be achieved during 1990s due to administrative, juridical and economic problems. Finally, Turkey initiated its electricity sector restructuring with the enactment of the Electricity Market Law (EML) of 2001 which was critical and most defiant milestone in liberalization process.

The main aim of the EML is the establishment of a competitive and liberalized electricity market based on bilateral contracts between buyers and sellers, together with a balancing and settlement mechanism. Legal unbundling and regulated third-party access (TPA) are other features of the EML. So far, an independent regulator has been established, market rules and TPA regime has been introduced, former public utility has been unbundled into generation, transmission and trade of electricity, distribution industry has been re-organized as in the form of 21 distribution regions, where all of them have been subjected to privatization process.

Following liberalization, most of the entrepreneurs opted for hydroelectric and natural gas technologies as shown in Table 1. During 2002–2010, a total of 752 licenses were given for hydropower plants and 211 licenses were given for natural gas plants. Meanwhile, the installed capacity of natural gas plants and hydropower plants increased to 83% and 29% respectively. In addition, wind energy has gained importance recently, and the installed

Table 1
Turkey's licensed and installed capacity by primary energy sources.
Source: Energy Market Regulatory Authority [27].

Number of licenses given										Total installed capacity (MW)			
Source	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (MW)**	**2002**	**2010**	**Change**	
Hydro	95	32	34	72	137	152	136	94	27956	12241	15831	3590	29.33%
Natural gas	44	11	22	8	5	20	23	78	16486	7247	13302	6055	83.55%
Wind	7	7	1	6	26	37	3	6	3500	19	1320	1301	6847.37%
Other renewable	5	4	0	1	6	3	2	11	299	45	201	156	346.67%
Other thermal	83	15	14	14	10	20	12	1	19628	12293	18870	6577	53.50%
Total	234	69	71	101	184	232	176	190	67869	31845	49524	17679	55.52%

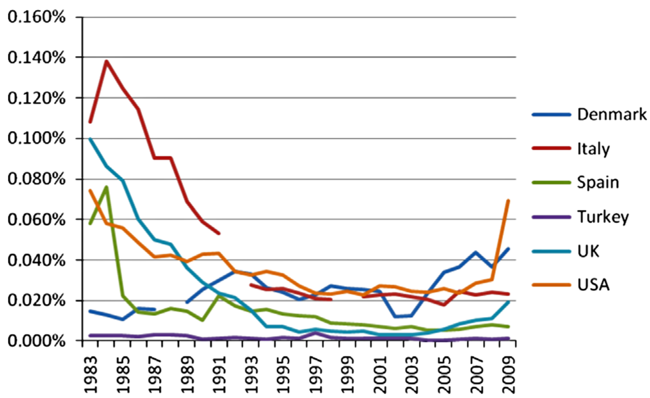


Fig. 1. Energy R&D budgets as a share of GDP.
Source: IEA [28].

capacity of wind has increased from 19 MW in 2002 to 1320 MW at the end of 2010.

5. Electricity R&D expenditures in Turkey

Government energy R&D expenditures (including demonstration expenditures) as a share of GDP have declined considerably in all countries in consideration since mid-80s as seen in Fig. 1. The decreasing support for nuclear industry and low oil prices (during 1985–2002) are considered as the major factors of this decline [8]. The impact of restructuring and privatization of public utilities are also considered another reasons for the decline in some countries. Recently, a slight increase in government energy R&D expenditures can be witnessed which is mostly attributed to increasing expenditures for environmental and sustainable energy technologies [8]. As shown in the figure, government energy R&D expenditures in Turkey has been very low compared to developed countries, and it has only increased from 6.6 million USD in 2000 to 8.9 million USD in 2009[5] which is only equal to 0.00131% of Turkey's GDP. [28].

Fossil fuel technologies received most of the R&D funds in 2009 in Turkey, followed by renewable energy technologies and hydrogen technologies as seen in Table 2. The share of hydrogen and fuel cell technologies increased considerably from null in 2003 to almost 39% in 2007, and then it declined under 20%. The main reason for this significant increase is the establishment of the International Centre for Hydrogen Energy Technologies (ICHET) in Turkey in 2004[6]. A significant aspect of government energy R&D expenditures in Turkey is the volatility of budget allocations to technologies. For example, fossil fuel technologies received nearly three quarter of all government energy R&D funds, but its share declined to 12% in 2006. One more example is the significant change in expenditures for nuclear energy R&D. In the early 90s, nuclear energy received nearly one fifth of government energy R&D budget; however, its share declined to almost null in recent years despite Turkey's efforts to build its first nuclear power plant.

Among renewable energy technologies, biofuels and solar energy technologies have received most of the government funds in 2009 as shown in Table 3. Turkey focused on renewable energy R&D since mid-90s, and solar energy and biofuels received most of the funds since then. Similar to other technologies, allocations for renewable energy technologies have varied during years. Another aspect of government renewable energy R&D is the very low R&D expenditures for wind and hydropower technologies. Although investors prefer hydropower and wind energy technologies over other renewable energy technologies in generation investments, the total share of wind energy and hydropower technologies in government energy R&D expenditures was lower than 1% in 2009.

Turkey has also a state-owned equipment manufacturing company—TEMSAN (Turkish Electromechanics Industry Co.)—that manufactures electro-mechanic equipments for hydropower plants. TEMSAN was established in 1977 with an aim to reduce import dependency in electro-mechanic equipments used in hydropower plants. Nonetheless, TEMSAN could not expand its manufacturing base despite growing demand, and it only started R&D projects in 2003. Currently, TEMSAN conducts R&D projects for micro- and mini-turbine designs, control–command systems for power systems, and it collaborates with TUBITAK, State Planning Organization and universities. According to TEMSAN's activity reports, growing private sector investments following electricity market reforms has created new demand and investment opportunities [29]. In this respect, TEMSAN has focused on R&D projects to strengthen its manufacturing base and develop new technologies. On the contrary to these targets, TEMSAN's R&D expenditures declined from 44,527 TL in 2007 (R&D intensity 0.13%) to 5705 TL in 2010 (R&D intensity 0.02%). In fact, 147,351 TL was spent for R&D expenditures in 2009 (R&D intensity 0.6%); however, financial constraints and slow down in R&D projects resulted in a steep decline in R&D expenditures in 2010[7] [29].

In private sector, electricity, gas and water supply R&D (EGWS) expenditures declined in real terms as seen in Fig. 2.[8] Since the mid-1990s, EGWS expenditures declined in all selected countries, and UK is the one with the greatest decline from 394 million USD in 1994 to 46 million USD in 2007. This decline may be attributed to the liberalization and deregulation process in electricity and gas

[5] At 2010 prices and exchange rates.

[6] ICHET is a project of the United Nations Industrial Development Organization (UNIDO) and aims to support hydrogen energy technologies in developing countries via R&D supports, demonstration projects and training courses.

[7] Research and development (R&D) intensity is the ratio of a firm's R&D expenditures compared to gross sales.

[8] At 2000 prices and exchange rates.

Table 2
Breakdown of Government Energy R&D expenditures in Turkey (%).
Source: IEA [28].

Type/Years	1990	1995	2000	2005	2006	2007	2008	2009
Energy efficiency	20.01	4.23	13.18	14.33	5.92	19.51	5.53	4.16
Fossil fuels	60.01	72.49	14.68	14.55	11.65	19.53	39.78	38.69
Renewable	20.01	1.58	34.46	39.32	31.43	16.05	25.03	27.77
Nuclear	20.01	15.87	4.29	0.00	12.68	0.00	0.94	0.00
Hydrogen and fuel cells	0.00	0.00	0.00	25.12	36.44	39.01	18.95	19.01
Other power tech.	0.00	0.00	31.87	1.62	1.75	2.98	3.99	5.69
Other research	0.00	6.34	1.52	5.05	0.15	2.91	5.79	4.70

Table 3
The share of government renewable energy R&D expenditures in government total energy R&D expenditures in Turkey.
Source: IEA [28].

Years	1990	1995	2000	2005	2006	2007	2008	2009
Solar energy	0.00	1.06	1.98	15.57	2.66	6.52	3.78	7.29
Wind energy	0.00	0.53	2.34	0.27	3.64	0.00	0.67	0.32
Ocean energy	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00
Biofuels	0.00	0.00	14.47	17.79	11.37	6.95	16.50	16.06
Geothermal energy	0.00	0.00	15.67	0.00	11.60	1.44	3.99	3.63
Hydroelectricity	0.00	0.00	0.00	5.68	1.39	0.15	0.00	0.40
Other renewable energy sources	0.00	0.00	0.00	0.00	0.00	1.00	0.10	0.08
Unallocated renewable energy sources	20.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

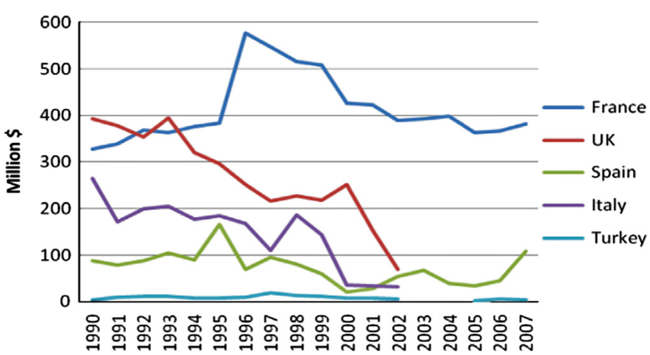


Fig. 2. Business enterprise real EGWS expenditures.
Source: OECD [30].

sectors during 1990s. EGWS expenditures increased in real terms during 1990–1997 in Turkey, but they declined from 18 million USD to 4 million USD during 1998–2007. Unlike other countries, Turkey initiated liberalization process in electricity sector in 2001 and in gas sector in 2002. Therefore, the impact of liberalization could not be witnessed in Turkey during 1990–2000. On the other hand, EGWS expenditures in Turkey in 2005 and 2007 were even below those of in 1994 and 2001 when Turkey had major economic crises[9] which may be attributed to the impact of liberalization after 2001.

The impact of electricity market liberalization on government and private energy R&D expenditures in Turkey was firstly discussed by Sirin who conducted a survey among transmission and natural gas companies [31]. According to survey results, electricity transmission and distribution companies have made organizational innovations mostly (a few made technological and marketing innovations), and none of these companies have performed R&D expenditures (although the transmission company participated in some R&D projects, its expenditures were covered by universities and TUBITAK) since 2001 when electricity market reforms were initiated. According to Sirin, regulatory uncertainties and uncompleted privatization of distribution companies were the main reasons that hamper technological innovations and R&D expenditures in Turkish electricity sector [31].

Following Sirin, a similar survey is conducted in this article, and private power companies and electrical equipment manufacturers were asked to answer three groups of questions regarding their R&D expenditures, obstacles in electricity sector that hinder R&D, and their opinion about the impact of liberalization on R&D expenditures[10]. Moreover, data are also retrieved through interview with managers and firms' web sites and activity reports. Power companies are selected among generation license owners that have a licensed capacity of more than 40 MW[11]. Equipment manufacturers are selected among the Turkey's Top 500 Industrial Companies 2011 list that was prepared by Istanbul Chamber of Industry [32].

Among the 60 power companies the survey was sent to, 44 responded to the survey of which results are presented in Table 3. Among the respondents, five have performed R&D expenditures, and only one of them has R&D intensity more than 1%. Thirty-six respondents have generation licenses for less than five years, and some of them began electricity generation in 2009. Only two of these companies have R&D expenditures, and 34 of these enterprises do not perform any R&D expenditures. All firms which perform R&D expenditures focus on renewable energy technologies, they collaborate with public agencies or universities, and two enterprises plan to increase their R&D expenditures in the next five years. They all channel their funds for experimental development, and they focus on improving/enhancing existing technologies (Table 4).

[9] Business enterprise performed 8.3 million USD in 1994 and 7.1 million USD in 2001 for EGWS in Turkey. On the other hand, EGWS expenditures have been 2.4 million USD in 2005 and 3.9 million USD for 2007 [30].

[10] According to Turkish accounting system R&D expenditures are recorded in line with Frascati Manual, and R&D expenditures are retrieved from financial tables of companies surveyed.

[11] According to regulations, power companies that have a licensed capacity of more than 40 MW or more have to audit their accounts to independent auditors (the limit was increased to 100 MW in November, 2011). Therefore, the survey was sent to these companies which makes easier to obtain R&D data.

Table 4
Survey results regarding power companies.

Firms with generation license	44	**R&D intensity in 2009**	**Number of Firms**
Of which use only renewable energy	30	$< 0.5\%$	3
Use only thermal resources	10	$0.5\% < x < 1.0\%$	1
Uses both	4	$1\% < x < 1.5\%$	0
Of which perform R&D expenditure	5	$> 1.5\%$	1
Perform no R&D expenditure	39		
Why firms do not perform R&D expenditures/ What hinder firms refraining from performing R&D expenditures in electricity sector	R&D expenditures are unnecessary		30
	Insufficient incentives/ Lack of capital/ High initial cost of R&D		9
	Regulatory & economic & demand uncertainties		5
	Lack of skilled workers/ problems in training		–
The impact of electricity market liberalization on R&D expenditures will be	Positive		8
	Negative		13
	No affect		5
	Do not know/undecided		18

When respondents asked why they do not perform R&D expenditures or the obstacles hampering R&D expenditures, more than half of the respondents stated that they were only focusing on power generation. Therefore, they perceive R&D expenditures as unnecessary, and they do not plan to conduct any R&D expenditures. Nine respondents stated insufficient incentives, lack of capital and high initial costs of R&D as main obstacles that hinder R&D expenditures. Five respondents think that economic, regulatory and demand uncertainties affect R&D expenditures adversely. Finally, no respondents put forward the lack of skilled workers and researchers in electricity sector as hindering problem for R&D projects.

When the respondents are asked about the impact of liberalization on electricity R&D expenditures, 18 respondents were undecided whether electricity market liberalization and deregulation have adverse effects on R&D expenditures in electricity sector. Eight respondents think that liberalization will have a positive effect on electricity R&D expenditures, while 13 respondents argue vice-versa. Five respondents think that liberalization will have neither positive nor negative effect on R&D expenditures.

Besides, power companies were asked about their equipment preferences, in order to assess the possible impacts on domestic equipment manufacturers' R&D expenditures. Companies stated that some equipment is bought from domestic manufacturers. On the other hand, some equipment is not produced in Turkey, and they have to be imported. In addition, some firms expressed their preference for foreign equipment over domestic equipment for quality and price reasons. While some respondents stated that they chose foreign equipment due to low prices compared to domestic ones, some stated they chose foreign equipment for its quality even if it is more expensive than domestic equipment.

A similar survey was sent to equipment manufacturers selected among the Turkey's Top 500 Industrial Companies list, and six companies responded to the survey. Five of these companies stated that they have performed R&D expenditures, and R&D intensity of these companies differs between 0.5% and 1.2%. Three of these companies stated that their R&D intensity has increased since liberalization, and the remaining two stated that their R&D intensity has not changed. Three of five companies have collaborated with government agencies and universities in R&D projects. All the five companies plan to continue performing R&D expenditures in the future, and three stated their plan to increase R&D intensity in the next five years. The company which has not performed R&D expenditures stated that it was just manufacturing equipments that were designed and developed in abroad.

When these companies were asked the obstacles in Turkey regarding R&D expenditures, they stated that insufficient incentives, regulatory uncertainties and demand problems create significant obstacles for performing R&D expenditures. Especially, cheap equipment imports from other countries poses a major threat for equipment manufacturers, and they stated that Turkey should take measures that foster domestic manufacturing. In addition, all these companies stated that liberalization has created new demand, and continuation of new investments will have a positive impact on their R&D expenditures.

6. Assessment of survey results and policy proposals for Turkey

The R&D data and the survey of companies clearly indicate that government electricity R&D expenditures are well below from developed countries, and power companies are refraining from R&D expenditures in Turkey. On the other hand, electricity market reforms had a positive impact on equipment manufacturers in terms of increasing demand. Nevertheless, these companies are also encountering problems due to low prices/quality reasons of imported equipments.

The problems in electricity sector necessitate the use of cleaner, cheaper and sustainable technologies, and new technologies can only be created by increasing and effective allocation of resources for R&D. Although technology transfer is the prevalent method in Turkey to acquire new technologies, growing energy demand may increase equipment imports and may become another source of problem in the coming decades. Moreover, R&D is required to develop and to enhance transferred knowledge/technology in order to meet local demands. In this context, the authors believe that Turkey should focus on energy-technology innovation which can be done primarily by taking measures to increase domestic R&D expenditures, to increase collaboration among domestic and foreign companies in technological innovations, and to participate in international/multinational R&D projects[12].

Turkey has recently taken significant steps to improve its innovation profile and to increase R&D expenditures. Within the context of the “2023 Vision Project”, three essential targets were decided regarding energy and natural resources: (1) prioritizing use of domestic natural resources in line with liberalized and transparent energy markets, (2) using secure, reliable, efficient and environment-friendly energy technologies and (3) developing energy technologies that can compete in global markets [33]. To achieve these targets, many domestic projects were initiated by

[12] Although R&D is only one aspect of technology development, and other supply-push (such as demonstration projects) and demand-pull measures are required to diffuse new technologies, the authors focused on measures to increase R&D expenditures in order to limit the scope of paper.

TUBITAK and government agencies, mostly focusing on renewable energy and clean coal technologies. Ministry of Energy and Natural Resources (MENR) and other institutions also use support mechanisms to raise R&D expenditures and encourage collaboration among business enterprises and government agencies [34]. On the other hand, a stable funding has not been achieved, and incentives are considered insufficient by investors as the survey results show. Therefore, government should allocate stable funding for R&D projects, and incentives for private sector should be increased. In this context, a positive development in Turkey is the introduction of support for use of domestically manufactured equipments in renewable energy plants in 2010. With the recent amendments made in Renewable Energy Law no.5346[13], renewable energy plant license owners get an additional bonus added to its feed-in tariff, if they use domestically manufactured equipments. According to this law, bonus payments vary according to source type and components [35]. For example, bonus payments for wind power plants are USD 0.008 for blades, USD 0.010 for generator and power electronics, USD 0.006 for tower and USD 0.013 for other mechanical parts in rotor and nacelle components. In hydropower plants, USD 0.013 is paid for turbines, and USD 0.010 is paid for generator and power electronics. This bonus payment is applicable to plants commissioned before 2015, and can be applied for five years. Although this support does not aim increasing R&D expenditures directly, it may encourage domestic manufacturers to focus on innovative activities and increase their R&D expenditures. Moreover, foreign companies may increase their R&D activities in Turkey as a result of bonus payments.

Another major problem with the low R&D expenditures is the economic and regulatory uncertainties. Although recent economic reforms helped to create a favorable climate for new investments, transition to a competitive and liberalized electricity market has not completed yet. In addition, most power companies do not perform R&D expenditures, and they do not collaborate with other enterprises or universities in innovative activities. Other countries also encountered similar problems during electricity market liberalization era, and power companies decreased or even annulled their R&D expenditures [36]. However, these companies have an important role in the commercialization of the knowledge created, and supporting power companies to perform R&D expenditures or to collaborate with universities and other business enterprises in innovative projects will help to foster innovative activities in Turkey. Moreover, some power companies demand equipments from domestic manufacturers as survey results show, and continuation of demand is essential for domestic manufacturers to fund their innovative activities; however the quality of domestic equipments should be improved in order to compete with foreign manufacturers and to attract domestic companies' interest in R&D. Therefore, incentives should also be directed for domestic manufacturers to improve their products' quality. Finally, general problems such as weak technological infrastructure, inadequacy of regulations regarding intellectual property rights create obstacles for innovative activities in electricity sector as in other sectors. Hence, improvement of technological infrastructure, alignment of regulations in line with EU *acquis* and strengthening of their enforcement would help to increase innovative activities and R&D expenditures.

Besides these measures, Turkey should focus on increasing international collaboration in energy R&D projects. Turkey has been a part of international efforts such as IEA Multilateral Technology Initiatives (Implementing Agreements) or EU's Framework Programmes for Research and Technological Development. Moreover, government agencies and domestic companies also cooperate with other foreign agencies and companies. Considering the lack of available funds for R&D investments in Turkey, more cooperation will enable government agencies and companies to benefit and learn from international experience. Although, there are also some problems in knowledge-share in these types of projects, this option is an appropriate choice to finance R&D projects and to enhance learning processes in the short-term.

[13] Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanılmasına İlişkin Kanun (in Turkish).

7. Conclusion

Turkey is a net energy importer, and it generates more than half of its electricity from imported fuels. The high share of imported fuels not only risks Turkey's supply security, but also creates economic and environmental burdens as well. Therefore, Turkey has to transform its electricity sector to a more sustainable pattern and should expand the use of cleaner and more efficient technologies and should focus on utilization of domestic resources. These can only be achieved by increasing domestic energy R&D expenditures, fostering technological innovations in electricity sector, and collaborating with other countries in developing new technologies. However, government energy R&D expenditures are very low compared to other OECD countries and private sector contribution to R&D expenditures is negligible.

In this article, the impact of electricity market liberalization on R&D expenditures in Turkey is assessed and policy proposals are discussed. Experiences of other countries show that liberalization has an adverse affect on both government and private energy R&D expenditures. Turkey has also witnessed a decrease in government energy R&D spending as a share of GDP and a decrease in business sector real EGWS expenditures. Moreover, results of the survey show that insufficient incentives and regulatory and economic uncertainties are argued as obstacles that hinder R&D expenditures in electricity sector. In addition to these uncertainties, lack of collaboration among enterprises, universities and government agencies, lack of funds and other problems create major obstacles for innovative activities and R&D expenditures in Turkey.

In order to overcome these problems Turkey should take measures to increase government and private R&D expenditures and should eliminate problems those hamper innovative activities in electricity sector. Moreover, increasing cooperation among domestic and foreign companies in R&D projects, and participation in multinational/international R&D and technology programmes will help Turkey to benefit from international experience.

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